BLASTNEL: Collision Sensation Display for Virtual Reality Games Using Highly Compressed Air

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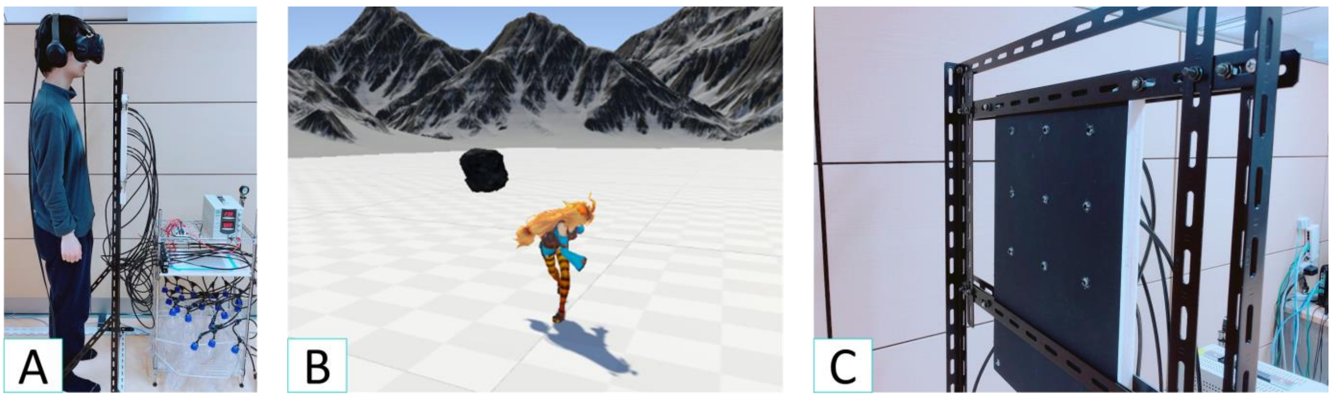

Figure 1: (A) BLASTNEL and a player. (B) The sight of the player. A girl is throwing a stone to the player. (C) Air nozzles on a panel. They jets out air to the player in synchronization with the collision of the stone.

ABSTRACT

In this paper, we propose "BLASTNEL", a collision sensation display for VR games using highly compressed air. BLASTNEL has multiple nozzles on a panel, and it can control the phase and duration of the jetting air from each nozzle. The player standing in front of the panel receives the jetting air when an object is collided to the player's character in the virtual world. The outline and duration of the jetting air are synchronized with those of the collision. Thus, BLASTNEL can improve the immersive feeling of the player. We developed a prototype and conducted a simple evaluation experiment. In this paper, we describe the responses of the subjects and the revealed issues.

CCS CONCEPTS

• Human-centered computing → Virtual reality • Hardware → Haptic devices

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KEYWORDS

Haptics, Force feedback, Collision sensation, Airflow, Blast, Highly compressed air, Virtual reality

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1 INTRODUCTION

Playing virtual reality (VR) games, the player can feel richer immersive feeling than playing traditional video games. That feeling will be strongly enhanced by haptic feedbacks that occur in synchronization with the events in the virtual environment. Collision sensation, the haptic feeling that arises whenever an object strikes hard against our body, is one of the important feedbacks to enhance the immersion. In the VR games, the character controlled by the player encounters various events associated with the collision sensation. For example, some enemies at close range attack the character with their weapons, and some enemies at long range shoot magic missiles at the character.

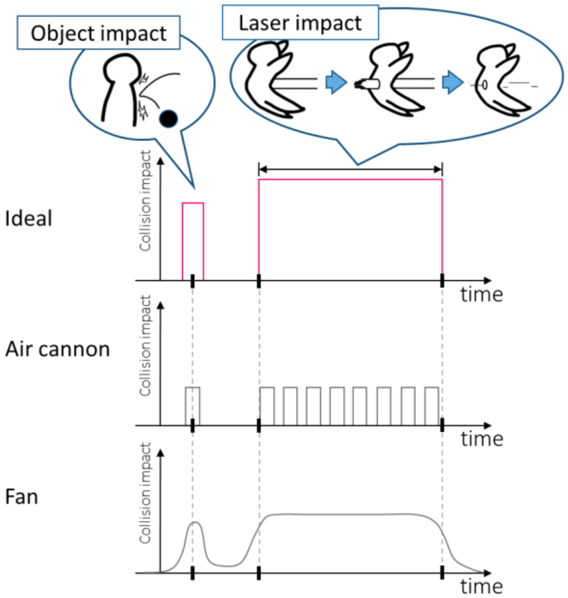

Figure 2: The relationships between the time transition and the impact of the collisions. The first collision is the bounce of an object. The second is the penetration of a continuous laser beam.

Hoppe et al (2018). developed a quadcopter that provides haptics in virtual reality [1]. In this system, a touchable surface extension is attached to the side of a quadcopter. This quadcopter is dynamically positioned in the real world to provide the user with haptic feedback that corresponds to the events in the virtual world. The shape of the extension is of three types. Each quadcopter with a different extension can provide a different kind of feedback.

However, the player character receives a variety of attacks from the enemies and environment. Some attacks might have linear outline with short duration contact, and some attacks might have broader outline with long duration contact. It is difficult for drone-based systems to respond to such attacks individually, for we must replace the extension to another to provide a feedback that has different outline and different duration contact.

We consider that we can reproduce such a variety of attacks by jetting air. We can feel the tactile sensation of air firmly if it is blown on our body. Jetting air for long duration can represent an inelastic collision, and vice versa. A spot blow from a nozzle might indicate a collision of a small object, and wide blow from multiple nozzles might indicate a collision of a large object. More importantly, air is flexible, safe, low-cost, and inexhaustible. In this paper, we propose "BLASTNEL", a haptic feedback system that uses highly compressed air. BLASTNEL has multiple air nozzles on a panel, and it can control the opening and closing of each nozzle. A VR-game player standing in front of the panel can receive jetting-air stimulation corresponding to the collision in the virtual world. We investigate the compatibility between the prototype system and some collisions in the virtual world.

2 RELATED WORK

A player of VR games receives haptic feedback as a virtual object hits the player's character. This feedback should have the same properties of the collision of the virtual object.

For example, a player feels impulse force feedback with middle-power as a snowball hits the body of the player's character. The player feels continuous force feedback with high-power compared to the snowball as the enemy irradiates laser beam to the player's character (The upper of figure 2).

Sodhi et al (2013). proposed "AIREAL", which delivers tactile sensation with air cannon displays [2]. An air vortex is fired from the cannon as a virtual object is coming to the character. Then, the vortex provides tactile feedback by hitting the player's body. This feedback is low-power and short-duration (The middle of figure 2).

Han et al (2018). proposes "Haptic Around", which provides full body experience in a virtual environment [3]. The system utilizes heat light, fan, hot air blower to recreate the non-contact tactile sensations from the environment. These feedbacks are low-resolution and have some delays until they come to the user's body (The lower of figure 2).

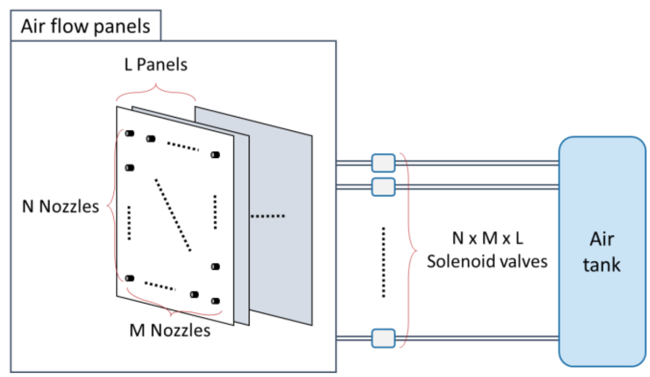

Figure 3: The concept of BLASTNEL.

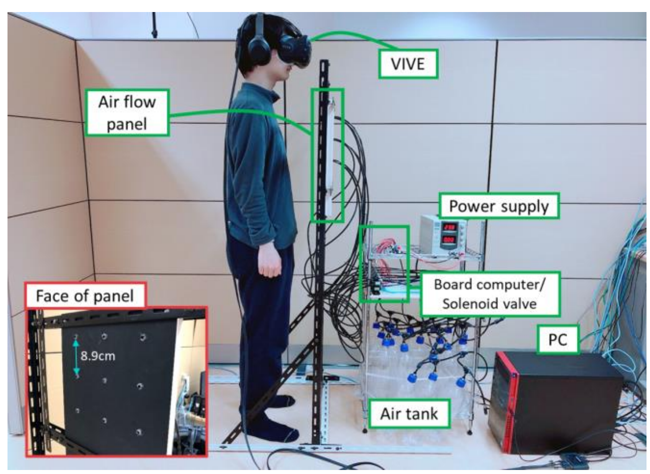

Figure 4: BLASTNEL prototype.

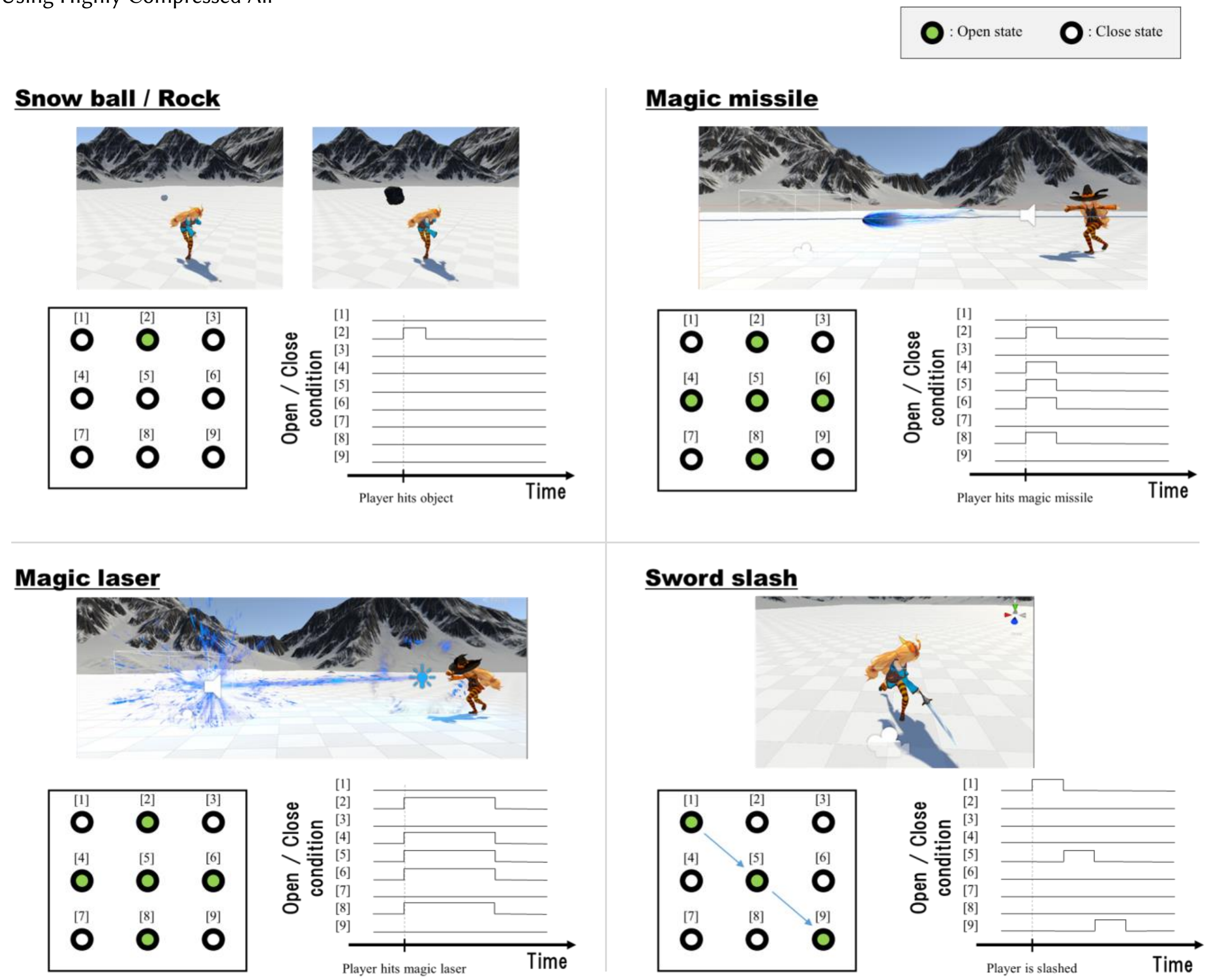

Figure 5: Unity-Chan's five attacks. The top of each attack shows the appearance of the collided object. The lower left indicates the active nozzle(s). The lower right shows the pulse patterns of each nozzle.

VR games have lots of collision events. Each of them has different power and duration. The air-based haptic devices described above could not handle the diversity.
In this study, we set three requirements:

1. Using highly compressed air for more power.
2. Stimulating multiple spots on the body in once or in sequence.
3. Controlling the duration from short to long.

3 BLASTNEL

3.1 Concept

We propose "BLASTNEL", a collision sensation display using highly compressed air (Figure 3). BLASTNEL consists of panels and an air tank. Each panel (hereinafter referred to as "airflow panel") has nozzles in a N x M grid layout. Each nozzle is connected to the air tank through a tube with a solenoid valve. The system can control the airflow jet out from the nozzle by opening and closing the solenoid valve.
Highly compressed air is strong enough to provide haptic feedback that corresponds to a collision of a massive object in the virtual world. The grid-layout nozzles on an airflow panel can express the size and contour of the object by controlling which nozzles are activated. The duration and phase of the airflow jet out from the nozzle can express how the object hit to the player's character.

3.2 Prototype

We developed a prototype system (Figure 4). The air tank supplies highly compressed air to each nozzle on the panel through the tube. A board computer can open and close each valve independently.
The player at the front of the panel can receive a variety of haptic feedbacks in synchronized with the events in the virtual

world by the air from the nozzles. The tank can store up to 0.6 MPa air.

3.2.1 Panel Design. The prototype has one panel, which has nine nozzles in a 3x3 grid layout. This matrix layout helps the system recreate two-dimensional geometry of the collided object in the virtual world. The distance between the neighboring nozzles is 8.9 cm (3.5 inch). This is determined based on the average shoulder width of Japanese men.

3.2.2 Virtual Environment. The virtual environment of the prototype is described with Unity. There are only two game characters in a snowy field. One substitutes as the player. This character is just standing at the same place in the field and does nothing. Another character (Unity-Chan: a blond-haired girl) is standing a little distance away, and attacks the player's character by five patterns (Figure 5).

"Snow ball" and "Huge rock" are clod-shaped objects in the virtual world. Unity-Chan picks and throws them at the player character. They provide a short-duration feedback. They both have the same active nozzle (the upper center #2) on the collision. "Magic missile" and "Laser beam" both have the same active nozzles (cross-shaped) but different durations. Unity-Chan shoots them from her hands after taking a backswing motion.

"Sword slash" has the bias active nozzles on the collision. Three nozzles are activated in sequence from top to bottom (#1, #5, then #9). Each feedback has short duration. In this case, Unity-Chan is spawned at the short distance of the player character and slashes down with the sword.

4 EVALUATION

We conducted an experiment to evaluated the collision sensations described in Section 3.2.3.

4.1 Procedure

A total of eight subjects (male:8, age:20-25) were participated in the experiment. Each subject was directed to put the HMD and to stand at the airflow panel. Then, Unity-Chan attacked the subject's character in the virtual environment in four different ways: "Snow ball", "Huge rock", "Magic missile", and "Laser beam". The subject experienced corresponding haptic feedbacks from the airflow panel. Following these four experiences, the subject was asked to choose "Like" or "Dislike" about each experience.

4.2 Result and Discussion

Figure 6 shows the result of the experiment. All the attacks got much "Like" than "Dislike". We could not confirm which attack was well suited to BLASTNEL. However, the positive answers indicated that BLASTNEL was favorably received by the subjects.

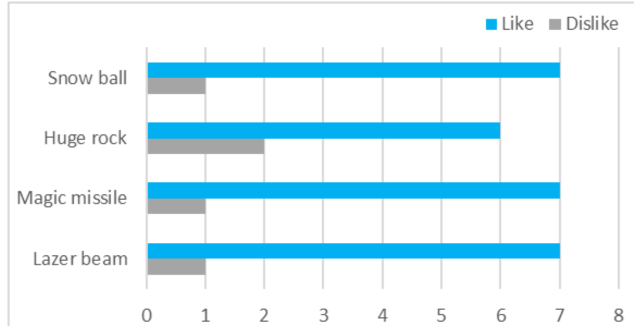

Figure 6: The result of "Like/Dislike" test.

In the free descriptive answers, we obtained negative but suggestive opinions about "Huge rock" from the subjects as follows.

1. I felt less feedback force than I thought.
2. I felt what collided with me was not like a stone, because the jets of air were cold for me.

Those answers suggested that we have to control the power(amplitude) and temperature of air jet. We would improve the former by introducing an air regulator for each air tube. For the latter, we would have to introduce heater or to investigate what kind of collision object would be fit for BLASTNEL.

5 CONCLUSION AND FUTURE WORK

In this paper, we proposed a collision sensation display for VR games using highly compressed air. From the evaluation experiment, we confirmed the following findings:

1. Most of the subjects answered positive responses about all colliding objects in the "Like/Dislike" test.
2. Some subjects felt that the jetting air was cold and the feedback force was subtle.

The experiment was conducted with "Like/Dislike" test, which was a two-alternative with coarse precision. For future work, we must investigate a detailed evaluation on each pattern using 7-point Likert scale. We are now trying to embed more nozzles on a panel and to add more panels to the air tank to enhance the two-dimensional spatial resolution of the stimulation. Such system would provide the user with a variety of stimulations corresponding to the collisions in the virtual environment.

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